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(72) Inventor GIUSEPPE ANGUZZA

(19)

(54) SEPARATING AIR TO PRODUCE OXYGEN AND/OR NITROGEN IN THE LIQUID STATE

(71) We, NUOVO PIGNONE S.P.A., an Italian Company, of Via. F. Matteucci 2, Firenze, Italy, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a process for producing oxygen and/or nitrogen in the liquid state.

According to the present invention, there is provided a process for producing oxygen and/or nitrogen in the liquid state, which comprises cooling feed air in a heat exchanger, partially liquefying the cooled air by expanding it through a first turbine and/or an expansion valve and subjecting the partially liquefied air to fractionation in a fractionating column from which liquefied oxygen and/or nitrogen is withdrawn, the pressure of the cooled air upstream of the turbine and/or the expansion valve being greater by from 1 to 3 atmospheres than that in the fractionating column, and a cooled component from the fractionating column being used to cool the feed air in the heat exchanger and thereafter being expanded in a second turbine which drives a load, said second turbine being present regardless of the absence or presence of said first turbine.

One embodiment of the process according to the present invention is that wherein the feed air is cooled by heat exchange with nitrogen withdrawn from the fractionating column, said nitrogen, after said heat exchange, being compressed in a compressor driven by said first turbine, and wherein said compressed nitrogen is thereafter expanded in said second turbine which drives a generator.

An alternative embodiment of the process according to the present invention is that wherein the feed air is cooled by heat exchange with gaseous air components withdrawn from the lower part of the fractionating column, said withdrawn gaseous air components, after said heat exchange, being expanded in said second turbine coupled to a brake-generator and said feed air also being expanded in said first turbine coupled to a brake-generator.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 illustrates a plant for carrying out the process of the present invention; and

each of Figures 2 to 6 illustrates a plant which is a modification of that shown in Figure 1.

In the plant of Figure 1, air is fed via a pipe 20 to a heat exchanger 1 where the air is cooled to a temperature near its dew point. The air, wholly deprived of water and carbon dioxide, is conveyed from the heat exchanger 1 via a pipe 21 to a heat exchanger 3, since a valve 2 in a pipe leading off pipe 21 is closed at this stage. In the heat exchanger 3 the air is preheated by a few degrees by heat exchange with nitrogen fed in a pipe 28 from a compressor-brake 9. The preheated air leaving the heat exchanger 3 in a pipe 22 is fed to a first turbine 4 and from here, after expansion, is fed via a pipe 23 to a fractionation column 5. A certain amount of pure nitrogen, corresponding to about 25% of the air fed in through pipe 20, is drawn off in a pipe 24 from the head of column 5 at a pressure of about 5 kg/cm² gauge (6 kg/cm² absolute), preheated in a condensing exchanger 6, withdrawn in a pipe 25 and then split into two streams. One stream is passed along the cold zone of heat exchanger 1, where it is subjected to a further heating, and is then passed in a pipe 26 to a valve 7, after which it is combined with the other stream which is passed through a valve 8, the recombined nitrogen streams are fed in a pipe 27 to a

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compressor-brake 9 where the nitrogen is compressed. The energy required for the compression is provided by the turbine 4 during the expansion of the air being processed; the compressor-brake 9 is directly linked to the driven shaft of the turbine 4.

The nitrogen compressed in the compressor-brake 9 is fed wholly (in a pipe 28) or partially to the heat exchanger 3, where it is cooled by thermal exchange with the air being processed, and then is fed in a pipe 29 to a second turbine 10 where it expands to a pressure of about 0.4 kg/cm² gauge (1.4 kg/cm² absolute).

The amount of nitrogen passing through the heat exchanger 3, prior to the expansion in turbine 10, is controlled by means of a valve 11 which operates in response to the temperature of the nitrogen in a pipe 30 coming from the turbine 10. The work produced by the expansion turbine 10 is recovered by a generator-brake 12.

Since the energy produced by turbine 4 is recovered in compressor-brake 9 during the compression of the nitrogen which will then expand in turbine 10, the whole energy produced by turbines 4 and 10 will be recovered by the generator-brake 12, taking into account, of course, the efficiency of the various machines.

The nitrogen, after expansion in the turbine 10, is fed in the pipe 30 to the heat exchanger 6 where it is heated with condensing air taken from the pipe 21. The liquid air formed in the exchanger 6 is conveyed in a pipe 32 to a valve 13 and then to the column 5. The nitrogen fed in pipe 30 to the heat exchanger 6, leaves the latter in a pipe 31 and is fed to the exchanger 1 where it is heated to room temperature by heat exchange, with the air to be processed entering the plant.

Valves 14 and 15 are the by-passes of the compressor-brake 4 and the turbine 10, respectively. The valve 14 is operated during gas production only, and valve 15 is opened when turbine 10 is stopped.

The pressure in fractionation column 5 is kept the same as that of the usual air fractionating plants by means of the barrage valve 2. The reference numeral 17 indicates a low pressure column.

The pressure upstream of valve 2 will be greater by from 1 to 3 atmospheres, than the operating pressure within column 5, depending on the amount of product in the liquid state to be produced.

With valve 2 closed, the whole air being processed is then expanded, with a production of external work, through turbine 4 (apart from that expanded through valve 13), from the air pressure at the plant inlet to the operating pressure of column 5.

The expansion of the air being processed occurs, at the inlet of turbine 4, from conditions of temperature and pressure slightly above the limiting curve of saturated vapour, whereas the conditions of the air at the outlet of turbine 4 are within the gas-liquid zone; therefore the air from turbine 4 is fed to the column 5, in small amounts in liquid state, and in larger amounts in gaseous state. Liquid nitrogen and liquid oxygen are withdrawn from column 5 by pipes (not shown).

The work produced by the air in turbine 4 is recovered by compressor-brake 9 which brings the nitrogen fed in pipe 27 to a higher pressure anid enthalpy level before being expanded through turbine 10, with the production of external work. The work produced by turbine 10 is recovered by generator-brake 12. Summing up, the work produced by turbines 4 and 10 is recovered by generator-brake 12, taking, of course, into account the relevant efficiencies.

The refrigeration units (i.e. the heat in kilocalories per hour extracted from the gas) produced by turbines 4 and 10 are about three times those produced by a single turbine in a plant for producing gaseous oxygen by means of a low pressure cycle.

A small increase in the operating pressure of the air to be processed by from 1 to 3 atmospheres, relative to the operating pressure in column 5 allows therefore a high production of refrigeration units and therefore a high percentage of products in liquid state.

In Figures 2 to 6 the reference numerals 1 to 15 indicate similar components as those indicated by corresponding numerals in Figure 1.

The modified plant shown by Figure 2 is similar to that shown in Figure 1 but the exchanger 3 is omitted. According to this modification, the air from the outlet of the heat exchanger 1, with the valve 2 totally closed, is fed directly to the turbine 4 and, after expansion in turbine 4, is fed to the column 5.

The modified plant shown in Figure 3 is similar to that shown in Figure 1 but the nitrogen in gaseous form in line 24 of Figure 1 has been replaced by gaseous air components taken from a lower part of the column 5, in fact about 25% of the whole processing air entering the plant.

The gaseous air components coming from column 5 are passed through the heat exchanger 6, where they are pre-heated by heat exchange with condensing air, and are then passed through the exchanger 1. The gaseous air components are then compressed by compressor-brake 9 and, after expansion in turbine 10, passed through a valve 16 before entering a low pressure column 17.

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The variant shown in Figure 4 is a modification of the plant shown in Figure 3 but, there being no exchanger 3, the processing air coming from heat exchanger 1 enters directly the turbine 4.

The variant shown in Figure 5 is a modification of the plant shown in Figure 4 where the compressor-brake 9 has been replaced by a generator-brake 18 serving to recover, in the form of electric power, the energy produced by the turbine 4. This replacement may be also applied to the preceding modifications—the nitrogen in pipe 27 is not compressed, but passes through the open valve 14.

The variant shown in Figure 6 is a modification of the plant shown in Figure 5 where the generator-brake 12 is replaced by a compressor-brake 19. This replacement may also be applied to the preceding modifications.

The present invention will now be illustrated by the following Example.

Example

The process of this Example was carried out in the plant as illustrated in Figure 1 of the accompanying drawing. In this Example all temperatures are expressed in °C and all pressures are expressed in kg/cm² absolute.

Air was fed at a temperature of +35 and at a pressure of 8.5 in pipe 20 to the heat exchanger 1 and the air leaving the heat exchanger 1 in pipe 21 was at a temperature of −166 and a pressure of 8.5. Much of the air in the pipe 21 was fed to the heat exchanger 3 and the air leaving the heat exchanger 3 in the pipe 22 had a temperature of −161.4 and a pressure of 8.2. This air was fed to the turbine 4 and the air leaving the turbine 4 in pipe 23 had a temperature of −171 and a pressure of 6; this expanded air was fed to the bottom of the fractionation column which operated at a pressure of 6.

Nitrogen leaving the fractionation column 5 was at a temperature of −177 and a pressure of 6 and was passed through the exchanger 6; the nitrogen left the exchanger 6 in a pipe 25 in which its temperature was −169 and its pressure was 5.85. 62% of the nitrogen in pipe 25 was passed through the heat exchanger 1 and then via pipe 26 (where its temperature was −93) to the valve 7, and the remaining 38% of the nitrogen in pipe 25 was passed directly through the valve 8. The recombined nitrogen stream in pipe 27 had a temperature of −122 and a pressure of 5.8; this nitrogen stream, after compression in compressor 9 had, in pipe 28, a temperature of −102 and a pressure of 9. Much of this compressed nitrogen was fed through the heat exchanger 3, and beyond the heat exchanger 3 it had, in pipe 29, a temperature of −123 and a pressure of 8.85. This nitrogen stream was expanded in the turbine 10 which it left in the pipe 30 where it had a temperature of −177 and a pressure of 1.4. The expanded nitrogen stream was fed to the exchanger 6 which it left in a pipe 31 where its temperature was −169 and its pressure was 1.36.

Part of the air in pipe 21 is drawn off and sent through the exchanger 6 where it is condensed; the condensed air leaves the exchanger 6 in a pipe 32 at a temperature of −170 and at a pressure of 8, this liquid air is expanded in the valve 13 and, on the downstream side of the valve 13 in pipe 33, the pressure of the air is 6; it is at this pressure that the air is introduced into the column 5.

The low pressure column 17 above the fractionation column 5 has an operating pressure of 1.5, and the temperature at the bottom of column 17 is −179 whereas at the top of column 17 the temperature is −193.

WHAT WE CLAIM IS:—

1. A process for producing oxygen and/or nitrogen in the liquid state, which comprises cooling feed air in a heat exchanger, partially liquefying the cooled air by expanding it through a first turbine and/or an expansion valve and subjecting the partially liquefied air to fractionation in a fractionating column from which liquefied oxygen and/or nitrogen is withdrawn, the pressure of the cooled air upstream of the turbine and/or the expansion valve being greater by from 1 to 3 atmospheres than that in the fractionating column, and a cooled component from the fractionating column being used to cool the feed air in the heat exchanger and thereafter being expanded in a second turbine which drives a load, said second turbine being present regardless of the absence or presence of said first turbine.

2. A process according to claim 1, wherein the feed air is cooled by heat exchange with nitrogen withdrawn from the fractionating column, said nitrogen, after said heat exchange, being compressed in a compressor driven by said first turbine, and wherein said compressed nitrogen is thereafter expanded in said second turbine which drives a generator.

3. A process according to claim 1, wherein the feed air is cooled by heat exchange with gaseous air components withdrawn from the lower part of the fractionating column, said withdrawn gaseous air components, after said heat exchange, being expanded in said second turbine coupled to a brake-generator and said feed air also being expanded in said first turbine coupled to a brake-generator.

4. A process substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

5. A process substantially as hereinbefore described with reference to any one of Figures 2 to 6 of the accompanying drawings.

6. A process substantially as described in the foregoing Example.

7. Oxygen and/or nitrogen in the liquid state, whenever produced by a process according to any preceding claim.

HASELTINE, LAKE & CO.,
Chartered Patent Agents,
28, Southampton Buildings,
Chancery Lane,
London, WC2A 1AT.
and
Temple Gate House,
Temple Gate,
Bristol, BS1 6PT
also
9 Park Square,
Leeds, LS1 2LH.

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1500610 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

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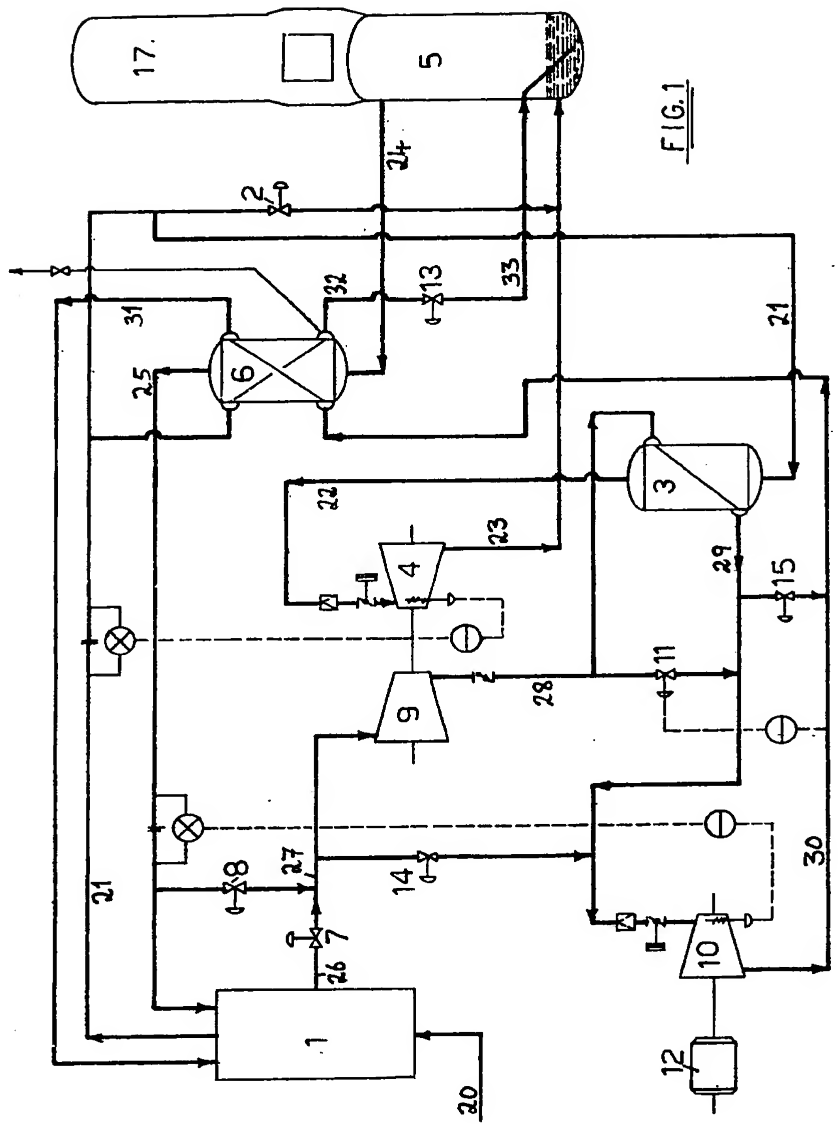

FIG.1

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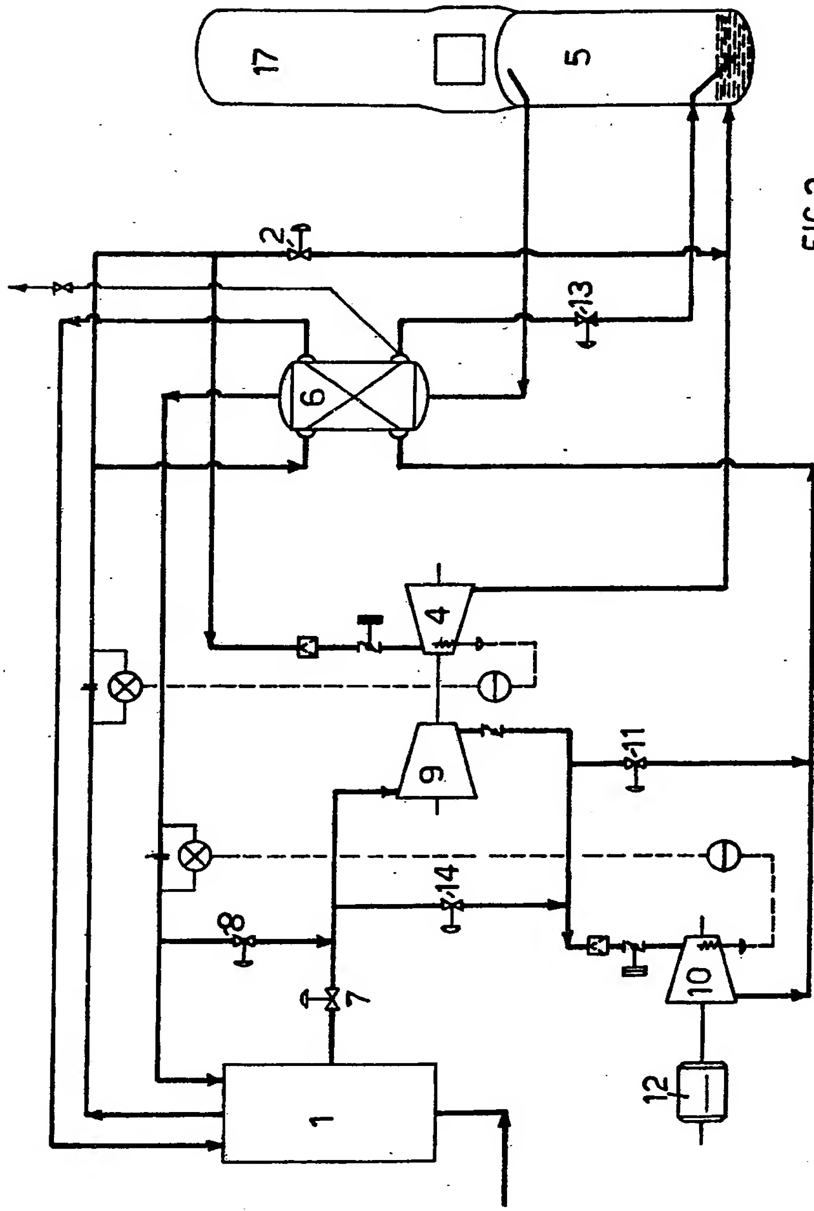

FIG.2

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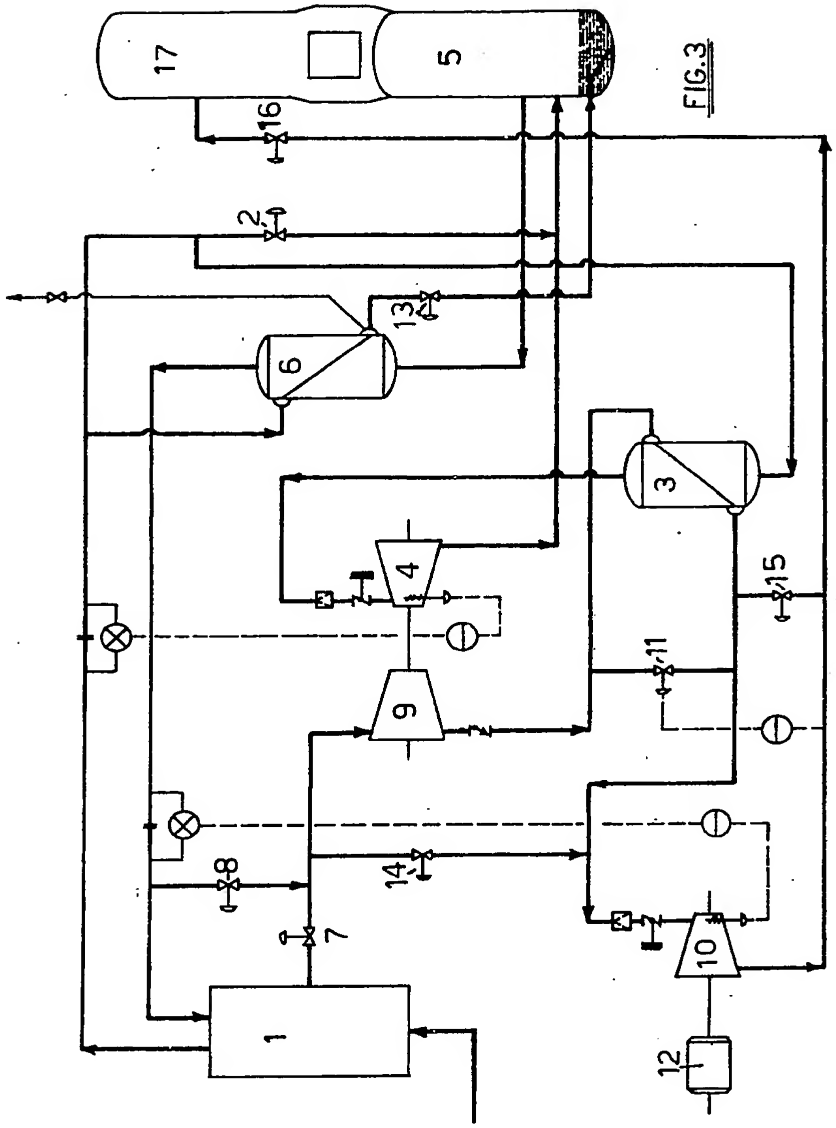

FIG.3

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1500610 COMPLETE SPECIFICATION

6 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 4

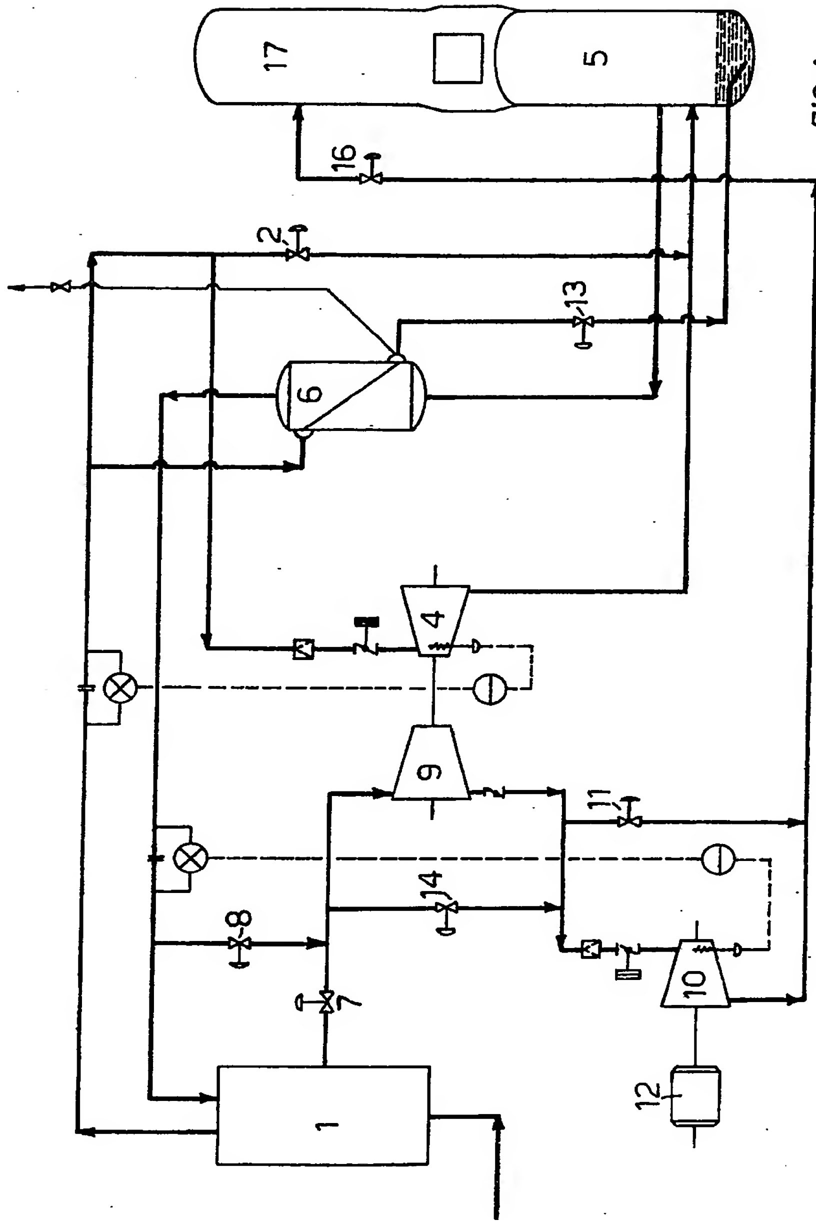

FIG.4

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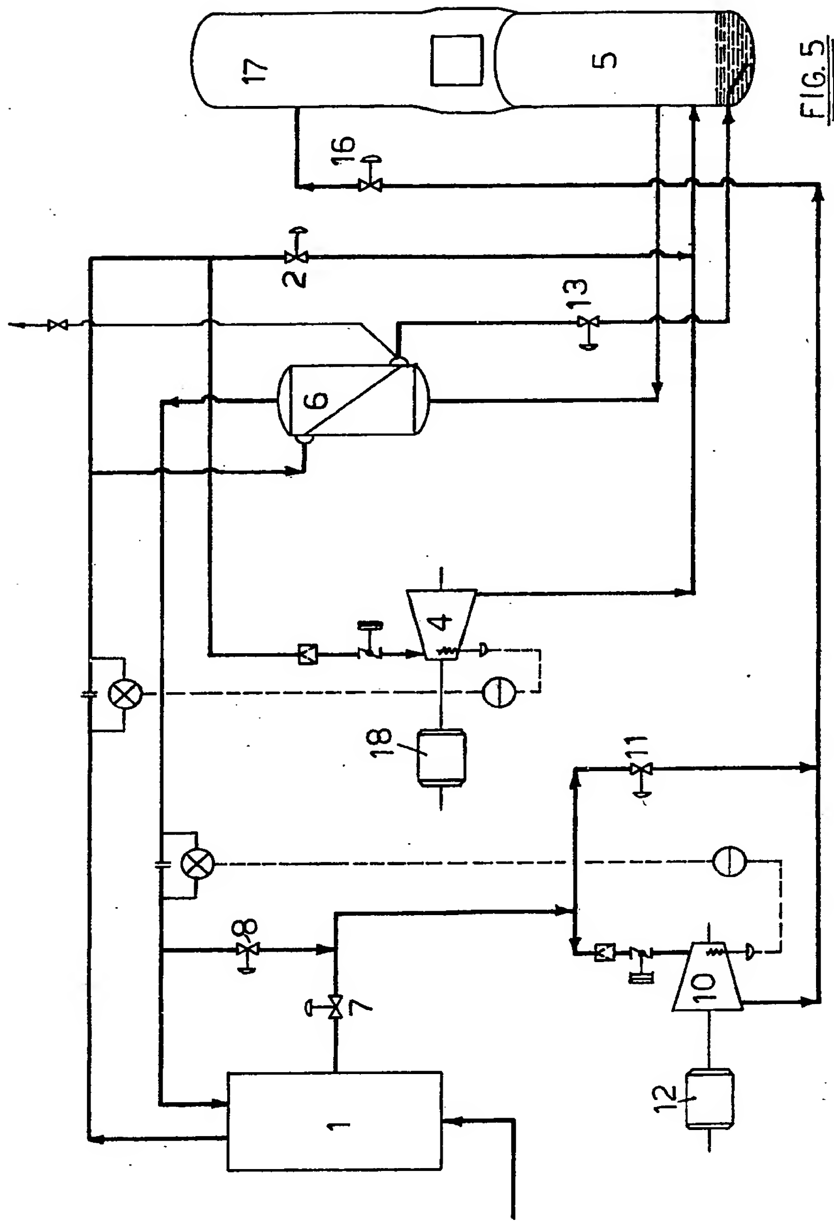

FIG. 5

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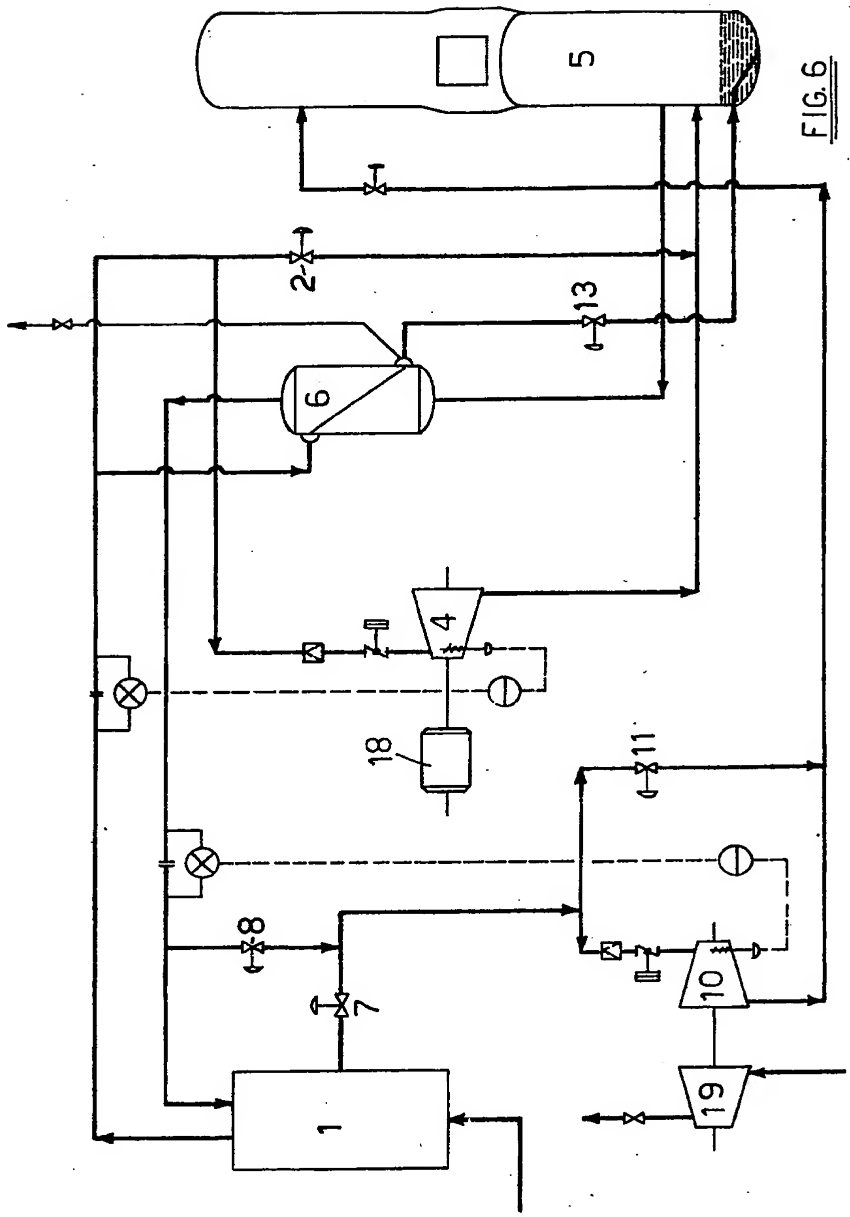

FIG. 6